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Imaging

Three-dimensional aesthetic assessment of class II patients before and after orthognathic surgery and its association with quantitative surgical changes

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Abstract. The aim of this study was to compare evaluations of the aesthetic outcome of class II orthognathic patients, as performed by observers with varying expertise using three-dimensional (3D) facial images, and to examine the relationship of aesthetic ratings in relation to quantitative surgical changes. Pre- and postoperative 3D facial images of 20 surgically treated class II patients (13 female, 7 male) were assessed for aesthetics by orthodontists, maxillofacial surgeons, and laypeople. Attractiveness ratings for the lips, chin, and overall facial aesthetics were evaluated on a 5-point Likert scale. Correlation between the aesthetic scores was obtained and quantitative surgical changes were examined. For all groups of observers, significant improvements in attractiveness scores were found, especially for the chin assessment. Orthodontists perceived the greatest improvement and laypeople the smallest. Overall, laypeople scored higher with less variability, but with lower intra- and inter-observer agreement. No significant correlation was found between the aesthetic improvement and soft tissue surgical changes. To avoid patient dissatisfaction, it is important to bear in mind that the demands and perception of aesthetic improvement after orthognathic surgery are higher for clinicians than for the general public.

Key words: face; aesthetics; attractiveness; perception; three-dimensional; class II; orthognathic surgery.

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Adult patients seeking orthodontic treatment seem to be largely driven by aesthetic concerns[1,2]. This is not surprising, since facial appearance plays a significant role in many aspects of life. Attractive individuals are perceived to be more successful and to have better social skills. They also appear to have higher self-esteem than their less attractive peers[3,4]. Combined

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orthodontic–orthognathic treatment is used routinely in non-growing skeletal class II patients to obtain a correct occlusion and skeletal relationship and to improve facial aesthetics. However, the perception of facial aesthetics is a complex issue because of its subjective nature. Establishing a well-balanced and attractive face can be challenging, because perceptions of aesthetic morphology may differ between clinicians and laypeople. Since patients are mainly judged by their peers, it is important to understand the differences in perception of facial attractiveness between professionals and society, in order to optimize treatment goals. Adequate communication between clinician and patient is also essential to avoid postoperative dissatisfaction[5].

In the literature, controversy remains as to whether laypeople and clinicians agree in their perceptions of facial attractiveness. General agreement between professionals and laypeople has been found in several studies[6–8]. Also, both clinicians and laypeople indicated better improvement in patients with large vertical and horizontal surgical changes in a previous study[9]. Other studies have suggested that laypeople are more tolerant than clinicians and show the greatest variation in what they consider attractive[10–13].

Various techniques have been used in the past to evaluate perceptions of facial aesthetics, such as silhouettes, photographs, and line drawings. All of these methods provide a two-dimensional (2D) view of a three-dimensional (3D) face. Considering the advancements made in digital imaging, it has since become possible to use 3D facial images with a high level of informational content.

The aims of the current study were (1) to analyze the aesthetic evaluations made by laypeople, orthodontists, and maxillofacial surgeons of the pre- and postsurgical 3D facial images of class II patients who had undergone orthognathic surgery, and (2) to examine the relationship between the aesthetic ratings and quantitative surgical changes.

Materials and methods

This study was registered and approved by the Medical Ethics Committee of the University Hospitals Leuven (Leuven, Belgium).

Patient selection

The inclusion criteria for patient selection were restricted to the following: (1) skeletal class II patients, (2) who had undergone orthognathic surgery at the Department of Oral and Maxillofacial Surgery of the University Hospitals Leuven between August 2014 and April 2016, and (3) for whom 3D facial images of sufficient quality, obtained before and at 6 months after surgery, were available. All patients meeting the inclusion criteria during the time period considered were selected. Patients with congenital malformations were excluded.

The study sample consisted of 20 patients (13 female and 7 male), aged between 15 and 56 years at the time of surgery (mean age 26 years). Sixteen patients underwent a bilateral sagittal split osteotomy advancement. One of these patients also received a genioplasty. A bimaxillary osteotomy was carried out in four patients, with three of the four undergoing an additional genioplasty. A bimaxillary procedure was performed in one patient because of an anterior open bite. In another patient, an additional maxillary advancement was done to improve facial aesthetics. Two patients underwent a counterclockwise rotation of the maxillomandibular complex to maximize chin projection. All patients provided informed consent for the use of their images in this study.

The mean surgical mandibular advancement was 4.24 mm (range 0.6–10.4 mm). The patients had a mean preoperative anterior lower facial height (ALFH) of 64.2 mm (range 53.7–83.7 mm), a mean upper to lower facial height ratio (UFH: LFH) of 79.3% (range 58.0–96.0%), and a mean mandibular plane angle (SNGoMe) of 33.6° (range 20.0–46.0°).

Imaging

For each patient, a 3D facial image of adequate quality was obtained before surgery (T0) and at 6 months after surgery (T1) (Fig. 1). All facial scans were obtained using a Planmeca ProMax 3D Mid unit (Planmeca Inc., Helsinki, Finland) under standardized conditions. Patients were scanned in natural head position with their eyes open and with a relaxed facial musculature.

Observers

The pre- and postsurgical facial images were judged by a panel of ten orthodontists (eight female, two male), five oral and maxillofacial surgeons (one female, four male), and four laypeople (two female, two male). The orthodontists and surgeons represented various levels of experience and were not involved in the treatment of the patients. All observers were adults. The group of laypeople consisted of staff members of the University Hospitals Leuven without training in dentistry.

Aesthetic assessment of the facial images

The subjects were assessed in four sessions, with five patients included in each session. For each session, pre- and postoperative 3D facial images were placed in random order

Fig. 1. Three-dimensional facial images obtained before and 6 months after surgery were presented to three groups of observers.

and presented using ProPlan software version 2.1 (Materialise, Leuven, Belgium). Observers were asked to evaluate the 3D facial images aesthetically on different levels using a 5-point Likert scale: 1 = very unattractive, 2 = unattractive, 3 = not attractive or unattractive, 4 = attractive, 5 = very attractive. For each facial image, an aesthetic score from 1 to 5 was given for lip attractiveness, chin attractiveness, and overall facial attractiveness. Observations were performed individually, undisturbed, and at the same computer. Each observer was able to manipulate the facial images in all directions to obtain an accurate 3D view. There was no time limit to complete the scoring. Instructions were given to evaluate the images in the most objective way and to use the whole scale.

At least 1 week before the actual assessment, a training session was organized to standardize the assessments of the observers. The training sample consisted of five class II patients (three female, two male), who were not included in the study sample. Pre- and postoperative 3D facial images were also placed in random order.

To assess intra-observer reliability, a second assessment round was performed by the same observers at least 1 week after the first observation. The four sessions were presented in a random order to re-evaluate the subjects.

Quantitative evaluation of the facial images

To quantify soft tissue facial changes, pre- and postoperative scans were imported into 3-matic software (version Medical 11; Materialise, Leuven, Belgium) and a protocol of five steps was followed, as shown in the flowchart in Fig. 2 and outlined below.

(1) Registration: Pre-surgical and postoperative scans were matched using the surface registration tool. Confounding regions such as hair, ears, and neck were removed.
(2) Identification of landmarks: In order to isolate the facial regions of the chin and the lips, soft tissue landmarks were identified to create reference planes using the method described by Verhoeven et al.[14], who developed a validated technique for the evaluation of facial asymmetry on 3D images. Nine soft tissue landmarks were identified manually: left (ExL) and right (ExR) exocanthion, sellion (Se), subnasale (Sn), left (AcL) and right (AcR) alar curvature, left (StmL)

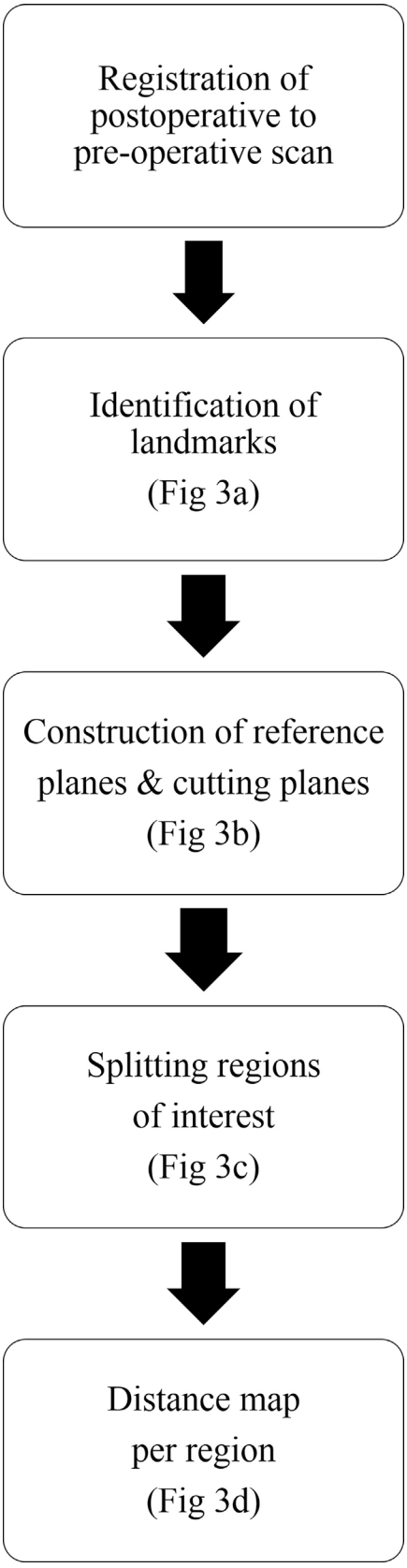

Fig. 2. Flowchart showing the five steps of the method used to quantify soft tissue facial changes.

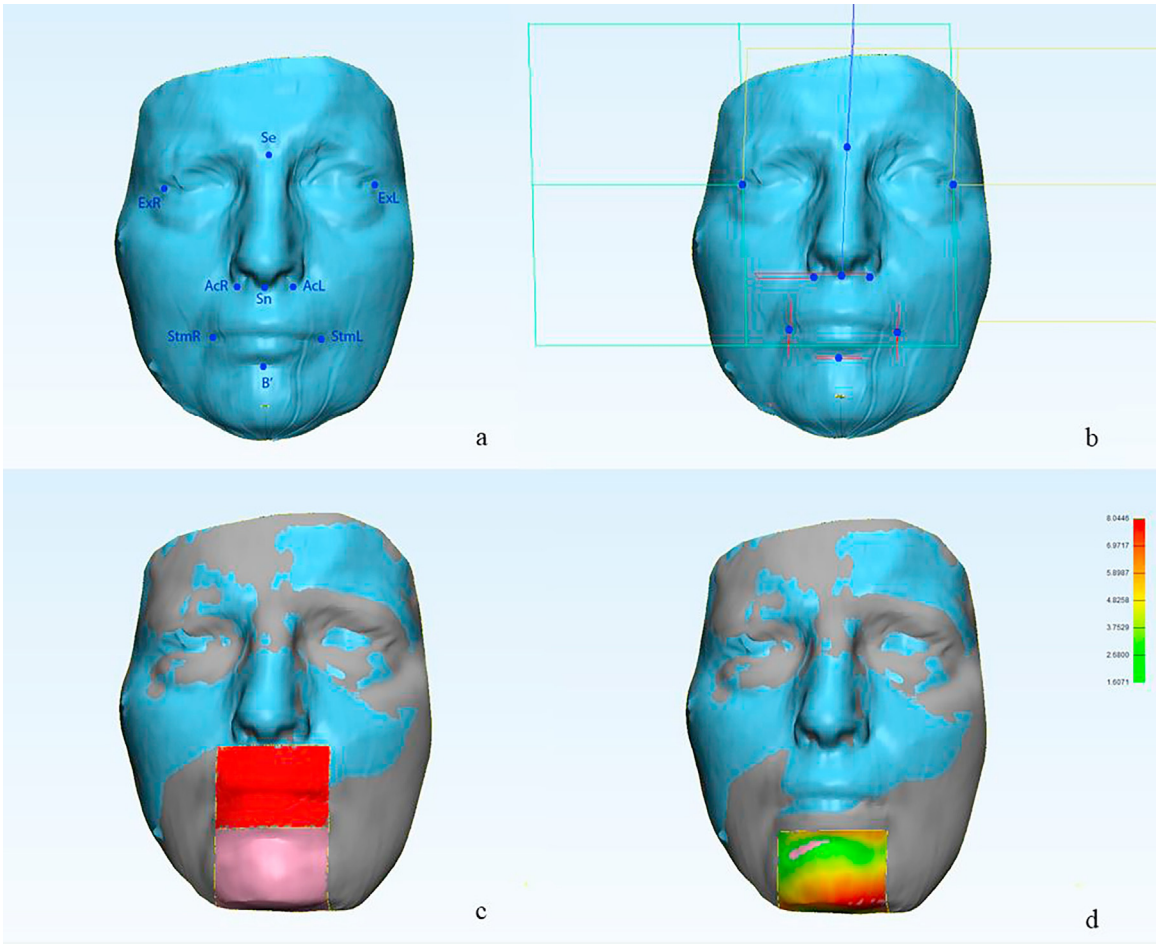

Fig. 3. To quantify soft tissue facial changes, nine soft tissue landmarks were determined (a), and reference planes and cutting planes were constructed (b) to isolate facial regions of the lips and the chin (c) and to calculate a distance map for the different areas (d).

and right (StmR) stomion, and soft tissue B-point (B′) (Fig. 3a).

(3) Construction of reference and cutting planes: Three reference planes were created in order to construct cutting planes to isolate the chin and lip regions. A transverse plane was identified through ExL, ExR, and Se. A coronal plane was constructed perpendicular to the transverse plane through both exocanthi. A sagittal plane was constructed through Se and Sn, perpendicular to the coronal plane. Afterwards, four cutting planes were created: a first plane through Sn, AcR, and AcL[14], a second plane through B′ and parallel to the first cutting plane, and another two planes parallel to the sagittal plane, with one through StmR and one through StmL (Fig. 3b).

(4) Splitting regions of interest: The regions of interest were split and isolated using the four cutting planes described (Fig. 3c).

(5) Distance maps: Finally, a distance map of the chin, the lips, and the overall facial image was obtained to evaluate the changes between the pre- and postoperative scans (Fig. 3d). The distance map is the Euclidean distance between every point on the surface of object 1 and its corresponding point on the surface of object 2. The software provides the mean, median, first quartile, third quartile, and the root mean square (RMS) of the surgical movements, illustrating the quantitative changes between the pre- and postoperative images for the different facial regions.

The same protocol was applied to five scans of four control subjects in order to evaluate the reproducibility of facial scans in patients without surgical treatment.

Statistical analysis

A linear mixed model was used to evaluate the mean difference in aesthetic rating before and after surgery in general and for the three separate observer groups, with observer and patient as the crossed random effect. *P*-values for differences between measurements before and after surgery were corrected for simultaneous hypothesis testing according to idák. A normal quantile plot of the residual values and a residual dot plot showed that the basic assumptions of normality and equal variability of residuals were met. Differences in scores between laypeople, orthodontists, and surgeons were analyzed with the unpaired Wilcoxon test. A bootstrap procedure was used to obtain *P*-values for the difference between observer groups for score variability. Intra- and inter-observer agreement was verified using Janson and Olsson's tau-statistics[15,16]. Spearman rank correlation coefficients were calculated to represent the relationship between quantitative surgical changes and changes in Likert scores before and after surgery. *P*-values were only considered significant if they were less than 0.05.

Results

Mean scores of attractiveness before and after surgery and the median and mean

Table 1. Mean scores of attractiveness at T0 and T1 and the improvement in the aesthetic assessment for the three observer groups.

Observer	Mean score T0	Mean score T1	Median T0–T1	Mean T0–T1	*P*-value	Improvement T1–T0 (%)	Worsening T1–T0 (%)	Unchanged T1–T0 (%)
Lips								
Orthodontists	2.69	3.37	−1.00	−0.68	0.0001*	65.00	19.50	15.50
Surgeons	2.69	3.21	−0.80	−0.52	0.0001*	60.00	24.00	16.00
Laypeople	3.03	3.25	0.00	−0.23	0.0439*	43.75	31.25	25.00
All observers	2.81	3.29	−0.05	−0.49	0.0001*	56.25	24.92	18.83
Chin								
Orthodontists	2.10	3.20	−1.00	−1.09	0.0001*	79.00	11.00	10.00
Surgeons	2.36	3.06	−1.00	−0.70	0.0001*	67.00	20.00	13.00
Laypeople	2.94	3.25	0.00	−0.31	0.0030*	48.75	22.50	28.75
All observers	2.45	3.18	−0.50	−0.73	0.0001*	64.92	17.83	17.25
Overall face								
Orthodontists	2.32	3.15	−1.00	−0.83	0.0001*	74.50	10.50	15.00
Surgeons	2.46	3.09	−0.50	−0.63	0.0001*	64.00	19.00	17.00
Laypeople	3.06	3.29	0.00	−0.23	0.0161*	46.25	13.75	40.00
All observers	2.61	3.19	−0.50	−0.58	0.0001*	61.58	14.42	24.00

* Significant difference.

Table 2. Differences in rating and differences in score variability between the three groups of observers.

Observers	Difference in mean score	*P*-value mean score	Difference in variability	*P*-value variability
Lips				
Orthodontists – surgeons	0.0875	0.2467	0.0389	0.6388
Orthodontists – laypeople	−0.1050	0.4112	0.1942	0.0110*
Surgeons – laypeople	−0.1925	0.0820	0.1553	0.0734
Chin				
Orthodontists – surgeons	−0.0575	0.4870	0.1488	0.0965
Orthodontists – laypeople	−0.4469	0.0000*	0.4701	0.0000*
Surgeons – laypeople	−0.3894	0.0001*	0.3213	0.0001*
Overall face				
Orthodontists – surgeons	−0.0387	0.9191	−0.0842	0.2966
Orthodontists – laypeople	−0.4419	0.0000*	0.2162	0.0023*
Surgeons – laypeople	−0.4031	0.0000*	0.3005	0.0009*

* Significant difference.

improvement in the aesthetic assessment for the three panel groups are presented in Table 1.

Attractiveness scores improved significantly after surgery, with a median improvement of 0.5 to 1.0 on the Likert scale. In particular, the attractiveness of the chin showed a significant improvement for each group of observers. Orthodontists reported a greater improvement in attractiveness than surgeons, and the lay group perceived the least improvement. In some cases, a worsening of aesthetics was reported post-surgically. Concerning changes to the chin and lips, a decrease in attractiveness was observed relatively more by laypeople. Maxillofacial surgeons reported relatively more worsening of the overall facial attractiveness. Worsening of facial aesthetics was least perceived by orthodontists.

Laypeople tended to give higher scores for the attractiveness of the chin and overall attractiveness. Scores for the attractiveness of the lips, the chin, and overall attractiveness were similar for orthodontists and maxillofacial surgeons. In general, the ratings of the laypeople also showed a significant lower variability than those of the orthodontists and the surgeons. Differences in rating and variability between the three groups of observers are shown in Table 2.

The intra- and inter-observer agreement values for the three groups of observers are presented in Table 3. Orthodontists and surgeons showed moderate to good agreement, while agreement was much lower for the lay group. Intra- and inter-observer agreement was highest for orthodontists.

Some consistency was found in this sample between pre-surgical aesthetic scores and the improvement after surgery. Patients with a low initial aesthetic score showed greater improvement in attractiveness for the lips, chin, and overall facial appearance. This was calculated only for the orthodontist scores, because of the good intra- and inter-observer reliability for this group of observers.

To assess the relationship between changes in aesthetic rating and surgical movement, differences in Likert scores (T1–T0) were compared with median and mean surgical changes and the RMS for lips, chin, and overall face. Spearman rank correlation coefficients were calcu-

Table 3. Intra- and inter-observer agreement for the three groups of observers.

Observer	Intra-observer agreement	*P*-value	Inter-observer agreement	*P*-value
Lips				
Orthodontists	0.57	0.00	0.47	0.00
Surgeons	0.21	0.00	0.21	0.00
Laypeople	0.03	0.00	0.08	0.00
Chin				
Orthodontists	0.62	0.00	0.53	0.00
Surgeons	0.22	0.00	0.28	0.00
Laypeople	0.18	0.00	0.10	0.00
Overall face				
Orthodontists	0.52	0.00	0.48	0.00
Surgeons	0.34	0.00	0.28	0.00
Laypeople	0.18	0.00	0.07	0.00

lated only for orthodontists and surgeons, because the results showed greater consistency in aesthetic rating for these two groups of observers. Coefficients representing the relationship between the surgical movement and changes in Likert scores before and after surgery are given in Table 4. In general, no significant correlation was found between the change in aesthetic score and surgical changes. For the median surgical change to the lips, a weak negative correlation was found with the change in Likert scores between T1 and T0, which would mean that a small surgical change implies a greater aesthetic improvement.

The reproducibility of the scanner was evaluated by performing the same measurements on five scans of four control patients. The results were consistently similar for the four controls with regard to the chin and the overall face and were significantly lower than the soft tissue movements in patients who had undergone surgical treatment. The results for the lips were inconsistent in only one control subject, showing almost similar quantitative changes as in the surgery patients. Details of the measurements are presented in Table 5.

Discussion

In general, the attractiveness of class II patients improved after orthognathic surgery. This is in agreement with previous findings[7,9,17–19].

In the literature, there is still debate regarding whether clinicians and laypersons differ in their perceptions of facial attractiveness. Several studies have found general agreement between professionals and the public[6,7,9,20], while others have found a significant difference in aesthetic perceptions between these groups[11,18,21–24]. In the present study, a significant difference in ratings of attractiveness among the three groups of observers was found. Laypeople gave higher scores and were apparently less demanding with regard to aesthetics than orthodontists and surgeons. Furthermore, laypeople rated with little variability and showed lower inter- and intra-observer agreement. Orthodontists perceived more improvement in attractiveness than surgeons, and laypeople perceived the least improvement, which is in agreement with other studies[23,25,26]. In some patients, a worsening of facial aesthetics was reported after surgery, which has also been found by other authors[7,19,27]. Laypeople perceived a decrease in attractiveness for the lips and the chin relatively more, while worsening of the overall facial attractiveness was observed more by surgeons.

The differences in aesthetic assessment between the three groups of observers are likely due to clinical experience and training. Maxillofacial surgeons and orthodontists are trained to critically evaluate the patient's profiles and to concentrate on certain facial regions. In this evaluation, orthodontists seemed to be more accepting of deviations than surgeons. For the inexperienced laypeople, it may be more difficult to keep a 'normal' class I profile in mind and to neglect other variables such as skin, eyes, and shape of the nose. This may explain why laypeople explored the Likert scale to a lesser extent and had a lower agreement. Tsang et al. also found a lower consistency in the ratings of laymen[27]. On the other hand, Maple et al. reported the highest correlation for laypeople and stated that clinicians might 'over-evaluate' profiles, while laypeople seem to give their initial reaction to the overall profile[6]. In some studies, laypeople were found to be more critical than professionals, which conflicts with the present study findings[18,24,28].

This study did not assess the influence of the gender of the observers and patients. Several authors have reported that attractiveness ratings are not influenced by the gender of the observers[18,22,29,30]. However, some differences were found in the literature with respect to the gender of the patient. In a study by Falkensammer et al., the male profile was rated less attractive than the female profile[22]. Lines et al. found that a slightly prominent chin was thought to be more attractive in males than in females[21]. This is in agreement with the study of de Almeida and Bittencourt[12], where surgery was more indicated for males in class II cases and for females in class III cases. Other authors have found that clinicians and non-clinicians are more sensitive to changes in females than to the same changes in males[20,23]. Knight and Keith found that facial expression had a greater influence in the ranking of female faces than in the ranking of male faces[30]. They speculated that clinicians and non-clinicians could be influenced by preferences in appearance while ranking the female faces. Ng et al., however, found

Table 4. Spearman rank correlation coefficients for the relationship between surgical movement and changes in aesthetic scores between T1 and T0.

Observer	Median surgical change	*P*-value	Mean surgical change	*P*-value	RMS of surgical change	*P*-value
Lips						
Orthodontists	−0.542	0.011*	−0.253	0.235	−0.114	0.592
Surgeons	−0.429	0.044*	−0.056	0.791	0.069	0.747
Chin						
Orthodontists	0.357	0.095	0.376	0.079	0.377	0.077
Surgeons	0.205	0.338	0.315	0.140	0.306	0.151
Overall face						
Orthodontists	−0.087	0.682	0.300	0.160	0.360	0.092
Surgeons	0.021	0.924	0.331	0.121	0.392	0.066

RMS, root mean square.
* Significant difference.

Table 5. Comparison of mean soft tissue changes (T1–T0) between the control group and the surgery group.

Soft tissue change (T1–T0)	Control group	Surgery group	*P*-value
Lips			
Median (mm)	0.696	1.155	0.069
Mean (mm)	0.778	1.154	0.005*
RMS (mm)	0.946	1.937	0.002*
Chin			
Median (mm)	0.855	4.320	0.000*
Mean (mm)	1.060	4.097	0.000*
RMS (mm)	1.307	4.431	0.000*
Overall face			
Median (mm)	0.399	0.616	0.001*
Mean (mm)	0.598	1.421	0.000*
RMS (mm)	0.860	2.215	0.000*

RMS, root mean square.
* Significant difference.

no difference among male and female patients[18].

This study found no significant correlation between the change in aesthetic score and the amount of soft tissue change due to surgery. According to previous research, a soft tissue mandibular advancement of 3 mm to 6 mm is critical to perceive an aesthetic change on 2D photographs or silhouettes[20,23,31]. The present study found no such threshold value of soft tissue movement that implies a significant change in aesthetic rating. Several factors could have contributed to these results. Firstly, 3D facial images represent facial characteristics in a more realistic way than silhouettes, line drawings, or 2D photographs. However, distracting factors such as skin tone, make-up, hairstyle, eyes, and age could not be eliminated and these may influence perceptions of aesthetics. Secondly, soft tissue advancement of the chin ranged from 0.57 mm to 9.01 mm for all included patients; there were no extreme advancement cases in this sample. Larger amounts of advancement could appear as a more evident change for the observers, especially untrained ones. Also, facial images were taken in natural head position with fixation of the head and support of the chin, to avoid distortion of the image due to movement. Support of the chin can lead to incomplete imaging of its lower border. In some patients, it was necessary to reconstruct a part of the chin surface with the 3-matic software to obtain a complete image. This may have influenced the quantitative results. Finally, it is important to mention that the sample size was rather limited and there was some variability in the sample regarding the extent of surgical treatment, ranging from a mandibular advancement alone to bimaxillary surgery with genioplasty.

Reproducibility of the position of the lips was low for one control subject. Also previous studies have found wide variability in the positions of the upper and lower lips[32–37]. The presence of labial brackets, difficulties in reproducing a relaxed lip position, and positional changes in the upper and lower incisors during orthodontic treatment may contribute to the less predictable lip position[32,38]. Also, data for the upper and lower lip were interpreted by the software as a continuous area rather than as two independent anatomical structures[37]. The large variability in lip position may explain why a weak negative correlation was found for the median surgical change of the lips with the change in aesthetic score.

It is important to emphasize that the perception of facial aesthetics is complex because of its subjective nature and can be influenced by many factors, such as education, socioeconomic status, ethnic background, age, and individual preferences[39,40].

For future research, it would be interesting to include a 3D evaluation of the underlying hard tissues. Extensive information from a virtual patient can be valuable in different maxillofacial research domains, for example in the 3D evaluation of soft-to-hard-tissue ratios after maxillofacial surgery, in the examination of the relationship between aesthetic perceptions and facial patterns, and in the definition of preoperative skeletal threshold values influencing aesthetic outcomes.

In conclusion, laypeople, orthodontists, and maxillofacial surgeons all perceived an improvement in attractiveness after orthognathic surgery in class II patients. In particular, the attractiveness of the chin showed a significant improvement for each group of observers. Laypeople tended to give higher scores with little variability and showed a lower level of inter- and intra-observer agreement. Orthodontists perceived the greatest improvement, while laymen detected the opposite. No significant correlation was found between the change in aesthetic score and the amount of soft tissue movement after surgery. To avoid patient dissatisfaction, it is important to bear in mind that the demands and perception of aesthetic improvement after orthognathic surgery are higher for clinicians than for the general public.

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Competing interests

Nothing to declare.

Ethical approval

This study was registered and approved by the Medical Ethics Committee of the University Hospitals Leuven (Leuven, Belgium), with registration number S57380.

Patient consent

Informed consent for the use of the clinical images in this study was provided by all of the patients.

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